

# **WIRING SUBSTRATE AND METHOD FOR MANUFACTURING THE SAME**

## **BACKGROUND OF THE INVENTION**

### **1. Field of the Invention**

5           The present invention relates to a wiring substrate and a method for manufacturing the same. The wiring substrate of the present invention can be used in a liquid crystal display device, an organic or inorganic EL (electroluminescent) display device, a plasma display device, an electrochromic display device, or the like.

### **2. Description of the Background Art**

10           On a TFT (thin film transistor) substrate used in a liquid crystal display device, or the like, a ring-shaped conductor pattern called "short ring" (hereinafter referred to as "SR") is provided along the periphery of the substrate in order to prevent an electrostatic discharge (hereinafter referred to as "ESD") damage while manufacturing the TFT  
15           substrate. Gate bus lines, storage capacitor lines, source bus lines, dummy lines, etc., are connected to SR. SR is typically removed in the scribing step or the beveling step after assembling the panel (see, for example, Japanese Laid-Open Patent Publication No. 8-234227).

20           FIG. 17 is a plan view schematically illustrating a TFT substrate being manufactured, after depositing a conductive film from which source bus lines are to be formed (hereinafter referred to also as "source film") across the entire surface of the substrate. FIG. 18 is a cross-sectional view taken along line D-D' of FIG. 17. A plurality of gate bus lines **GL** extending in the row direction, a plurality of storage capacitor lines **Cs** extending parallel to the gate bus lines **GL**, and gate terminals **GT** for  
25           electrically connecting the gate bus lines **GL** with the IC chip are formed on the substrate. In a case where the routing of the lines is difficult because of spatial limitations, a storage

capacitor stem **CsT** connecting together a plurality of storage capacitor lines **Cs** may need to be provided between the gate bus lines **GL** and the gate terminals **GT**, as illustrated in FIG. 17, for example. Thus, there are gate metal lines connected to SR (e.g., the storage capacitor stem **CsT**, the gate bus lines **GL** and the dummy lines), and gate metal islands not connected to SR (e.g., COG (chip on glass) gate terminals and COG source terminals).

Moreover, a terminal **VT** for supplying a power supply voltage to the IC chip and other lines (not shown) for inputting driving signals to the IC chip are formed in an IC chip attachment area **AA**. A gate insulating film **GI** and a source film **SF** are successively deposited on these line patterns.

The gate insulating film **GI** includes a through hole **GO** near one end of each of the gate bus lines **GL** and the gate terminals **GT**. The charge that has been accumulated on the gate metal islands due to triboelectric charging, or the like, in the manufacturing process up to the deposition of the source film **SF** flows to the lines connected to SR via the through holes **GO** upon deposition of the source film **SF**. Thus, as the charge accumulated on the gate metal islands is released to SR, the lines on the substrate are all brought to an equipotential state. Note that the gate insulating film **GI** also includes the through holes **GO** in regions where the gate terminals **GT** overlap with the IC chip attachment area **AA**.

The deposited source film **SF** is then patterned to form source bus lines **SL** and connection patterns **CP** for connecting the gate bus lines **GL** with the gate terminals **GT**. FIG. 19 is a plan view schematically illustrating the TFT substrate after patterning the source film **SF**.

However, ESD occurs in a case where the distance between the through hole **GO** of a gate metal island and a gate metal line is shorter than the distance between the through hole **GO** of the gate island and the through hole **GO** of the gate metal line, e.g., in a case where the distance "a" between the through hole **GO** of the gate terminal **GT** and

the storage capacitor stem **CsT** is shorter than the distance "b" between the through hole **GO** of the gate terminal **GT** and the through hole **GO** of the gate bus line **GL**. FIG. 20 is a cross-sectional view illustrating an occurrence of ESD. On the instant the source film **SF** is deposited, before the entire surface of the substrate is brought to an equipotential state, the potential difference (charge) created between the gate island and the gate metal line due to triboelectric charging, or the like, passes to a gate metal line portion that is closest to the gate island, thereby causing ESD.

FIG. 21 is a plan view illustrating the location where ESD occurs. In a case where ESD occurs in an area where a connection pattern **CP** for connecting the gate bus line **GL** with the gate terminal **GT** is formed, as illustrated in FIG. 21, a leak occurs between the gate bus line **GL** and the storage capacitor line **Cs**, thereby making the product defective.

### SUMMARY OF THE INVENTION

It is an object of the present invention to reduce the possibility of a product to become defective due to ESD, in other words, to improve the production yield, to reduce the manufacturing cost, and to improve the throughput.

According to the present invention, in a case where some portions of the TFT are in an island structure, for example, a contact window is provided in the insulating film on the short ring near the islands so that the charge (potential difference) created in the islands is allowed to flow to the short ring using a film to be deposited thereafter. Thus, it is possible to prevent an ESD damage.

Even in a case where the contact window cannot be provided, the line patterns are arranged so that ESD occurs selectively at locations around the island patterns such that the occurrence of ESD will not influence the quality of the final product. Therefore, it is possible to improve the production yield, to reduce the manufacturing cost, and to improve

the throughput.

A wiring substrate according to the first aspect of the present invention is a wiring substrate, including a short ring formed along a periphery of the substrate, an independent line pattern that is coplanar with and independent of the short ring, a continuous line pattern that is located closest to the independent line pattern and is coplanar and continuous with the short ring, and an insulating film covering the independent line pattern and the continuous line pattern, wherein the insulating film includes a first through hole reaching the independent line pattern and a second through hole reaching the continuous line pattern.

It is preferred that a distance between the first through hole and the continuous line pattern is longer than a distance between the second through hole and the continuous line pattern along a virtual line extending between the first through hole and the second through hole. Herein, the distance between the first or second through hole and the continuous line pattern is the shortest distance, along the surface of the insulating film, between the edge of the opening of the first or second through hole and the edge of the continuous line pattern. The term "distance" as used herein refers to a distance defined in a plan view.

A wiring substrate according to the second aspect of the present invention is a wiring substrate, including a short ring formed along a periphery of the substrate, an independent line pattern that is coplanar with and independent of the short ring, a first continuous line pattern that is coplanar and continuous with the short ring, a second continuous line pattern that is located between the independent line pattern and the first continuous line pattern and is coplanar and continuous with the short ring, and an insulating film covering the independent line pattern and the first and second continuous line patterns, wherein: the insulating film includes a first through hole reaching the independent line pattern, a second through hole reaching the first continuous line pattern,

and a third through hole reaching the second continuous line pattern; the independent line pattern and the first continuous line pattern are electrically connected to each other by a connection pattern bridging the second continuous line pattern via the first through hole and the second through hole; and the third through hole is formed in an area other than an area where the connection pattern is formed.

A wiring substrate according to the third aspect of the present invention is a wiring substrate, including a short ring formed along a periphery of the substrate, an independent line pattern that is coplanar with and independent of the short ring, a first continuous line pattern that is coplanar and continuous with the short ring, a second continuous line pattern that is located between the independent line pattern and the first continuous line pattern and is coplanar and continuous with the short ring, and an insulating film covering the independent line pattern and the first and second continuous line patterns, wherein: the insulating film includes a first through hole reaching the independent line pattern and a second through hole reaching the first continuous line pattern; the independent line pattern and the first continuous line pattern are electrically connected to each other by a connection pattern bridging the second continuous line pattern via the first through hole and the second through hole; the second continuous line pattern includes a protruding portion that is located in an area other than an area where the connection pattern is formed and is protruding toward the independent line pattern while being coplanar with the short ring; and a distance between the first through hole and the second continuous line pattern in the area where the connection pattern is formed is longer than a distance between the first through hole and the protruding portion.

In the wiring substrate according to the third aspect of the present invention, it is preferred that the insulating film includes a third through hole reaching the protruding portion in the area where the protruding portion is formed. In such a case, it is preferred that a distance between the first through hole and the second continuous line pattern in the

area where the connection pattern is formed is longer than a distance between the first through hole and the third through hole.

In the wiring substrate according to the third aspect of the present invention, the connection pattern may be electrically connected to the protruding portion via the third through hole, and the protruding portion may be independent of the second continuous line pattern.

In the wiring substrate according to the second aspect of the present invention, it is preferred that a distance between the first through hole and the second continuous line pattern is longer than a distance between the third through hole and the second continuous line pattern along a virtual line extending between the first through hole and the third through hole. Moreover, in the wiring substrate according to the third aspect of the present invention, wherein the insulating film includes a third through hole reaching the protruding portion in the area where the protruding portion is formed, it is preferred that a distance between the first through hole and the second continuous line pattern is longer than a distance between the third through hole and the second continuous line pattern along a virtual line extending between the first through hole and the third through hole.

A display apparatus of the present invention includes a wiring substrate of the present invention.

A manufacturing method according to the first aspect of the present invention is a method for manufacturing the wiring substrate according to the second or third aspect of the present invention, the method including the steps of: forming the first through hole and the second through hole in the insulating film; forming a conductive film on the substrate; and patterning the conductive film so as to form the connection pattern.

A manufacturing method according to the second aspect of the present invention is a method for manufacturing the wiring substrate according to the third aspect of the present invention, wherein: the insulating film includes a third through hole reaching

the protruding portion in the area where the protruding portion is formed; and the connection pattern is electrically connected to the protruding portion via the third through hole, and the protruding portion is independent of the second continuous line pattern, the method including the steps of: forming the first through hole, the second through hole and the third through hole in the insulating film; forming a conductive film on the substrate; 5 patterning the conductive film so as to form the connection pattern; and cutting off a connecting portion between the protruding portion and the second continuous line pattern.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

10           FIG. 1 is a schematic plan view illustrating a wiring substrate of Embodiment 1.

          FIG. 2 is a cross-sectional view taken along line II-II of FIG. 1.

          FIG. 3 is a schematic plan view illustrating a wiring substrate of Embodiment 2.

15           FIG. 4 is a cross-sectional view taken along line IV-IV of FIG. 3.

          FIG. 5 is a schematic plan view illustrating a wiring substrate of Embodiment 3.

          FIG. 6 is a cross-sectional view taken along line VI-VI of FIG. 5.

          FIG. 7 is a schematic plan view illustrating a wiring substrate of Embodiment 20 4.

          FIG. 8 is a schematic plan view illustrating a wiring substrate of Embodiment 5.

          FIG. 9 is a plan view illustrating an occurrence of a leak between a gate insulating film **GI** and a storage capacitor stem **CsT** via a connection pattern **CP**.

25           FIG. 10 is a plan view schematically illustrating an entire wiring substrate of one example of the present invention.

FIG. 11A, FIG. 11B and FIG. 11C are cross-sectional views illustrating various steps for manufacturing the wiring substrate, taken along line A-A', line B-B' and line C-C', respectively, of FIG. 10.

FIG. 12 is a plan view schematically illustrating the wiring substrate in Step 1.

5 FIG. 13 is a plan view schematically illustrating the wiring substrate in Step 2.

FIG. 14 is a plan view schematically illustrating the wiring substrate in Step 3.

FIG. 15 is a plan view schematically illustrating the wiring substrate in Step 4.

FIG. 16 is a plan view schematically illustrating the wiring substrate in Step 5.

10 FIG. 17 is a plan view schematically illustrating a TFT substrate being manufactured, after depositing a source film across the entire surface of the substrate.

FIG. 18 is a cross-sectional view taken along line D-D' of FIG. 17.

FIG. 19 is a plan view schematically illustrating the TFT substrate after patterning the source film.

FIG. 20 is a cross-sectional view illustrating an occurrence of ESD.

15 FIG. 21 is a plan view illustrating the location where ESD occurs.

FIG. 22 is a schematic plan view illustrating an occurrence of ESD in a case where the distance 1 is shorter than the distance 2.

## **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

20 Preferred embodiments of the present invention will now be described with reference to the drawings.

### **EMBODIMENT 1**

25 A wiring substrate of Embodiment 1 is an embodiment of a wiring substrate according to the first aspect of the present invention. FIG. 1 is a schematic plan view illustrating the wiring substrate of Embodiment 1, and FIG. 2 is a cross-sectional view



taken along line II-II of FIG. 1.

The wiring substrate of the present embodiment includes SR (not shown) formed along the periphery of the substrate, the gate terminal **GT** that is coplanar with and independent of SR, the storage capacitor stem **CsT** that is located closest to the gate terminal **GT** and is coplanar and continuous with SR, and the gate insulating film **GI** covering the gate terminal **GT** and the storage capacitor stem **CsT**. The gate insulating film **GI** includes a first through hole **GO1** reaching the gate terminal **GT**, and a second through hole **GO2** reaching the storage capacitor stem **CsT**.

The gate insulating film **GI** includes an opening above the storage capacitor stem **CsT** located closest to the electrically-isolated gate terminal **GT**. Therefore, on the instant the source film **SF** is deposited, the charge accumulated on the gate terminal **GT** moves to the storage capacitor stem **CsT**, which is connected to SR, via the first through hole **GO1** and the second through hole **GO2**. Thus, it is possible to prevent ESD.

It is preferred that the distance 1 between the first through hole **GO1** and the storage capacitor stem **CsT** is longer than the distance 2 between the second through hole **GO2** and the storage capacitor stem **CsT** along the virtual line extending between the first through hole **GO1** and the second through hole **GO2**. When the source film **SF** is deposited by a sputtering method or a CVD (chemical vapor deposition) method, an electrical connection is established between the gate terminal **GT** and the storage capacitor stem **CsT** via the first through hole **GO1** and the second through hole **GO2** at or near the midpoint of the virtual line extending between the first through hole **GO1** and the second through hole **GO2**.

Note that in the present embodiment, the distance 1 between the first through hole **GO1** and the storage capacitor stem **CsT** is, strictly speaking, the shortest distance between the edge of a portion of the surface of the gate terminal **GT** that is exposed through the first through hole **GO1** and the edge of the storage capacitor stem **CsT**.

Similarly, the distance 2 between the second through hole **GO2** and the storage capacitor stem **CsT** is the shortest distance between the edge of a portion of the surface of the storage capacitor stem **CsT** that is exposed through the second through hole **GO2** and the edge of the storage capacitor stem **CsT**.

5               FIG. 22 is a schematic plan view illustrating an occurrence of ESD in a case where the distance 1 is shorter than the distance 2. When the distance 1 is shorter than the distance 2, the charge accumulated on the gate terminal **GT** passes to the edge of the storage capacitor stem **CsT** close to the first through hole **GO1**, thereby causing ESD, before an electrical connection is established between the gate terminal **GT** and the storage  
10   capacitor line via the first through hole **GO1** and the second through hole **GO2**. When the distance 1 is longer than the distance 2, the charge accumulated on the gate terminal **GT** moves to the storage capacitor stem **CsT** via the second through hole **GO2** because an electrical connection is established between the gate terminal **GT** and the storage capacitor line via the first through hole **GO1** and the second through hole **GO2** before the charge  
15   passes to the edge of the storage capacitor stem **CsT**. Therefore, it is possible to more reliably prevent ESD by setting the distance 1 to be longer than the distance 2.

## EMBODIMENT 2

A wiring substrate of Embodiment 2 is an embodiment of a wiring substrate  
20   according to the second aspect of the present invention. FIG. 3 is a schematic plan view illustrating the wiring substrate of Embodiment 2, and FIG. 4 is a cross-sectional view taken along line IV-IV of FIG. 3.

The wiring substrate of the present embodiment includes **SR** (not shown) formed along the periphery of the substrate, the gate terminal **GT** that is coplanar with and  
25   independent of **SR**, the gate bus line **GL** that is coplanar and continuous with **SR**, the storage capacitor stem **CsT** that is located between the gate terminal **GT** and the gate bus

line **GL** and is coplanar and continuous with **SR**, and the gate insulating film **GI** covering the gate terminal **GT**, the gate bus line **GL** and the storage capacitor stem **CsT**. The gate insulating film **GI** includes the first through hole **GO1** reaching the gate terminal **GT**, the second through hole **GO2** reaching the gate bus line **GL**, and a third through hole **GO3** reaching the storage capacitor stem **CsT**.

The gate terminal **GT** and the gate bus line **GL** are electrically connected to each other by the connection pattern **CP** bridging the storage capacitor stem **CsT** via the first through hole **GO1** and the second through hole **GO2**. The third through hole **GO3** is formed in an area other than the area where the connection pattern **CP** is formed.

The gate insulating film **GI** includes an opening above the storage capacitor stem **CsT** located closest to the electrically-isolated gate terminal **GT**. Therefore, on the instant the source film **SF** is deposited, the charge accumulated on the gate terminal **GT** moves to the storage capacitor stem **CsT**, which is connected to **SR**, via the first through hole **GO1** and the third through hole **GO3**. Thus, it is possible to prevent ESD. The third through hole **GO3** is formed in an area other than the area where the connection pattern **CP** is formed. In other words, the portion of the source film **SF** that is in the area of the third through hole **GO3** is removed when the connection pattern **CP** is formed by a photolithography method. Therefore, it is possible to prevent a leak between the gate bus line **GL** and the storage capacitor stem **CsT**.

It is preferred that the distance 1 between the first through hole **GO1** and the storage capacitor stem **CsT** is longer than the distance 2 between the third through hole **GO3** and the storage capacitor stem **CsT** along the virtual line extending between the first through hole **GO1** and the third through hole **GO3**. Thus, it is possible to more reliably prevent ESD.

Note that in the present embodiment, the virtual line extending between the first through hole **GO1** and the third through hole **GO3** is a line of the shortest path

between the edge of a portion of the surface of the gate terminal **GT** that is exposed through the first through hole **GO1** and the edge of a portion of the surface of the storage capacitor stem **CsT** that is exposed through the third through hole **GO3**. The distance 1 between the first through hole **GO1** and the storage capacitor stem **CsT** is the distance, along the virtual line, between the edge of a portion of the surface of the gate terminal **GT** that is exposed through the first through hole **GO1** and the edge of the storage capacitor stem **CsT**. Similarly, the distance 2 between the third through hole **GO3** and the storage capacitor stem **CsT** is the distance, along the virtual line, between the edge of a portion of the surface of the storage capacitor stem **CsT** that is exposed through the third through hole **GO3** and the edge of the storage capacitor stem **CsT**.

### EMBODIMENT 3

A wiring substrate of Embodiment 3 is an embodiment of a wiring substrate according to the third aspect of the present invention. FIG. 5 is a schematic plan view illustrating the wiring substrate of Embodiment 3, and FIG. 6 is a cross-sectional view taken along line VI-VI of FIG. 5.

The wiring substrate of the present embodiment includes **SR** (not shown) formed along the periphery of the substrate, the gate terminal **GT** that is coplanar with and independent of **SR**, the gate bus line **GL** that is coplanar and continuous with **SR**, the storage capacitor stem **CsT** that is located between the gate terminal **GT** and the gate bus line **GL** and is coplanar and continuous with **SR**, and the gate insulating film **GI** covering the gate terminal **GT**, the gate bus line **GL** and the storage capacitor stem **CsT**. The gate insulating film **GI** includes the first through hole **GO1** reaching the gate terminal **GT**, and the second through hole **GO2** reaching the gate bus line **GL**.

The gate terminal **GT** and the gate bus line **GL** are electrically connected to each other by the connection pattern **CP** bridging the storage capacitor stem **CsT** via the

first through hole **GO1** and the second through hole **GO2**. The storage capacitor stem **CsT** includes a protruding portion **CN** in an area other than the area where the connection pattern **CP** is formed. The protruding portion **CN** is coplanar with **SR** and is protruding toward the gate terminal **GT**. The distance 3 between the first through hole **GO1** and the storage capacitor stem **CsT** in the area where the connection pattern **CP** is formed is longer than the distance 4 between the first through hole **GO1** and the protruding portion **CN**.

On the instant the source film **SF** is deposited, before the entire surface of the substrate is brought to an equipotential state, the potential difference (charge) created between the gate terminal **GT** and the lines connected to **SR** due to triboelectric charging, or the like, passes to the closest line portion connected to **SR**, i.e., the protruding portion **CN** of the storage capacitor stem **CsT**, thereby causing ESD (see FIG. 6).

Moreover, the pattern of the protruding portion **CN** is formed in an area other than the area where the connection pattern **CP** is formed. Thus, it is possible to prevent a leak, via ESD, between the gate bus line **GL** and the storage capacitor stem **CsT**, thereby improving the production yield of the final products.

Note that in the present embodiment, the distance 3 between the first through hole **GO1** and the storage capacitor stem **CsT** in the area where the connection pattern **CP** is formed is, strictly speaking, the shortest distance between the edge of a portion of the surface of the gate terminal **GT** that is exposed through the first through hole **GO1** and the edge of the storage capacitor stem **CsT** in the area where the connection pattern **CP** is formed. Similarly, the distance 4 between the first through hole **GO1** and the protruding portion **CN** is the shortest distance between the edge of a portion of the surface of the gate terminal **GT** that is exposed through the first through hole **GO1** and the edge of the protruding portion **CN**.

#### EMBODIMENT 4

A wiring substrate of Embodiment 4 is a variation of Embodiment 3. FIG. 7 is a schematic plan view illustrating the wiring substrate of Embodiment 4.

In the wiring substrate of the present embodiment, the gate insulating film **GI** includes the third through hole **GO3** reaching the protruding portion **CN** in the area where the protruding portion **CN** is formed. The charge accumulated on the gate terminal **GT** is urged to pass to the protruding portion **CN** that is closest to the gate terminal **GT**. When the gate insulating film **GI** includes the third through hole **GO3** above the protruding portion **CN**, the resistance when ESD is caused is considerably larger than the resistance when a charge passes to the protruding portion **CN** via the third through hole **GO3**, whereby the charge passes along the path of the lower resistance. Thus, the charge accumulated on the gate terminal **GT** passes to the protruding portion **CN** via the third through hole **GO3**. Therefore, by forming the third through hole **GO3**, it is possible to suppress the occurrence of ESD.

It is preferred that the distance 1 between the first through hole **GO1** and the protruding portion **CN** is longer than the distance 2 between the third through hole **GO3** and the protruding portion **CN** along the virtual line extending between the first through hole **GO1** and the third through hole **GO3**. Thus, it is possible to more reliably prevent ESD.

Note that in the present embodiment, the virtual line extending between the first through hole **GO1** and the third through hole **GO3** is a line of the shortest path between the edge of a portion of the surface of the gate terminal **GT** that is exposed through the first through hole **GO1** and the edge of a portion of the surface of the protruding portion **CN** that is exposed through the third through hole **GO3**. The distance 1 between the first through hole **GO1** and the protruding portion **CN** is the distance, along the virtual line, between the edge of a portion of the surface of the gate terminal **GT** that is exposed through the first through hole **GO1** and the edge of the protruding portion **CN**.

Similarly, the distance 2 between the third through hole **GO3** and the protruding portion **CN** is the distance, along the virtual line, between the edge of a portion of the surface of the protruding portion **CN** that is exposed through the third through hole **GO3** and the edge of the protruding portion **CN**.

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## EMBODIMENT 5

A wiring substrate of Embodiment 5 is a variation of Embodiment 4. FIG. 8 is a schematic plan view illustrating the wiring substrate of Embodiment 5. As illustrated in FIG. 8, the distance 3 between the first through hole **GO1** and the storage capacitor stem **CsT** in the area where the connection pattern **CP** is formed is longer than the distance 5 between the first through hole **GO1** and the third through hole **GO3**. Thus, it is possible to more reliably suppress the occurrence of ESD in the area where the connection pattern **CP** is formed.

Note that in the present embodiment, the distance 5 between the first through hole **GO1** and the third through hole **GO3** is the shortest distance between the edge of a portion of the surface of the gate terminal **GT** that is exposed through the first through hole **GO1** and the edge of a portion of the surface of the protruding portion **CN** that is exposed through the third through hole **GO3**.

After the source film **SF** is deposited and patterned, a patterning defect such as a film residue (a portion of a film remaining in an area where the film is intended to be removed) or pattern deformation may occur due to dust (foreign matter). In the wiring substrate of the present embodiment, the connection pattern **CP** may inadvertently be electrically connected to the protruding portion **CN** via the third through hole **GO3** because of a patterning defect such as a film residue or pattern deformation due to dust, thereby causing a leak between the gate terminal **GT** and the storage capacitor stem **CsT**. FIG. 9 is a plan view illustrating an occurrence of a leak between the gate terminal **GT** and

the storage capacitor stem **CsT** via the connection pattern **CP**. In the wiring substrate illustrated in FIG. 9, the connection pattern **CP** is patterned in a distorted planar shape because of a patterning defect such as a film residue due to dust, whereby the connection pattern **CP** is electrically connected to the protruding portion **CN** via the third through hole **GO3**. Thus, a leak occurs between the gate terminal **GT** and the storage capacitor stem **CsT** via the connection pattern **CP** connecting the first through hole **GO1** with the third through hole **GO3**.

Such an abnormal wiring substrate can be detected during an inspection step, or the like. A wiring substrate that is detected to be abnormal can be subjected to a repair step to rectify the leak. Specifically, a connecting portion **P** between the protruding portion **CN** and the storage capacitor stem **CsT** can be cut off so that the protruding portion **CN** becomes independent of the storage capacitor stem **CsT**, thereby avoiding a signal leak between the gate terminal **GT** and the storage capacitor stem **CsT**. The connecting portion **P** can be cut off by using, for example, an energy beam such as a laser beam or an ion beam. It is preferred that the connecting portion **P** of the protruding portion **CN** of the storage capacitor stem **CsT** is narrow in width so that the connecting portion **P** can be cut off in a subsequent repair step by using a laser beam, or the like. For example, the width of the connecting portion **P** may be about 3 to 20  $\mu\text{m}$ , and preferably about 5 to 10  $\mu\text{m}$ .

#### EXAMPLE

FIG. 10 is a plan view schematically illustrating an entire wiring substrate of one example of the present invention. The wiring substrate of this example includes an active area section **I**, a gate terminal section **II** and a source terminal section **III**.

The wiring substrate of this example includes **SR** formed along the periphery of the substrate, the gate terminals **GT** and source terminals **ST** each being coplanar with



and independent of SR, and the gate bus lines **GL** and the storage capacitor lines **Cs** each being coplanar and continuous with SR. The gate bus lines **GL** and the storage capacitor lines **Cs** are extending in parallel to each other in the row direction. The storage capacitor stem **CsT** connecting together a plurality of storage capacitor lines **Cs** extends in the column direction between the gate bus lines **GL** and the gate terminals **GT**. Moreover, the terminal **VT** for supplying a power supply voltage to the IC chip is formed in the IC chip attachment area.

A first protruding portion **CN1** protruding from the storage capacitor stem **CsT** is located between the gate terminals **GT**, arranged in the column direction. Moreover, a second protruding portion **CN2** protruding from the storage capacitor line **Cs** is located between the source terminals **ST**, arranged in the row direction. A gate insulating film (not shown) is deposited on these line patterns. The gate insulating film includes the first through holes **GO1** and the second through holes **GO2** near one end of the gate terminals **GT** and the gate bus lines **GL**, respectively. Each gate terminal **GT** is electrically connected to the corresponding gate bus line **GL** by the connection pattern **CP** bridging the storage capacitor stem **CsT** via the first through hole **GO1** and the second through hole **GO2**. Similarly, the gate insulating film includes the third through holes **GO3** near the end of the first and second protruding portions **CN1** and **CN2**.

The source bus lines **SL** extending in the column direction are formed on the gate insulating film. A TFT is formed near each intersection between the source bus line **SL** and the gate bus line **GL**. A pixel electrode **PE** is formed in each area that is partitioned by the source bus lines **SL** and the gate bus lines **GL**, with a plurality of pixel electrodes **PE** being arranged in a matrix pattern in the active area section **I**. Each pixel electrode **PE** is connected to the corresponding TFT via a contact hole **CH**. One end of each source bus line **SL** overlaps with the corresponding source terminal **ST** via the gate insulating film. The gate insulating film includes the first through holes **GO1** each in the

area where the source terminal **ST** is formed. Each source bus line **SL** and the corresponding source terminal **ST** are electrically connected to each other via the first through hole **GO1** formed in the gate insulating film.

Next, the steps of manufacturing the wiring substrate of this example will be described with reference to the drawings. FIG. 11A, FIG. 11B and FIG. 11C are cross-sectional views illustrating various steps for manufacturing the wiring substrate, taken along line A-A', line B-B' and line C-C', respectively, of FIG. 10. FIG. 12 to FIG. 16 are plan views schematically illustrating the wiring substrate in various steps.

#### STEP 1

A conductive film, from which gate bus lines, etc., are to be formed, is deposited on a cleaned insulative substrate, e.g., a glass substrate, by using a reactive sputtering apparatus. For example, a conductive film of TiN/Al/Ti (50/100/30 nm) is deposited. After a resist film is patterned by a photolithography process, or the like, the gate bus lines, etc., are formed by using a reactive ion etching (RIE)-mode dry etcher, for example, and the resist is stripped away by using a chemical solution such as a resist stripper solution (see FIG. 12). As illustrated in FIG. 12, the gate terminals **GT** and the gate bus lines **GL** are opposing each other in the row direction with the storage capacitor stem **CsT** therebetween. The gate bus lines **GL**, the storage capacitor stem **CsT** and the storage capacitor lines **Cs** are connected to **SR**.

The gate terminals **GT** and the source terminals **ST** are in an island structure and are not connected to **SR**. In this example, two gate terminals **GT** are provided immediately adjacent to the first protruding portion **CN1** protruding from the storage capacitor stem **CsT** so that the gate terminals **GT** are opposing each other in the column direction with the first protruding portion **CN1** therebetween. Moreover, two source terminals **ST** are provided immediately adjacent to the second protruding portion **CN2**

protruding from the storage capacitor line **Cs** so that the source terminals **ST** are opposing each other in the row direction with the second protruding portion **CN2** therebetween. By forming a conductive film to be described later, from which the source bus lines **SL** are to be formed, on the gate insulating film **GI** to be described later, the gate terminals **GT** and the source terminals **ST** are electrically connected to **SR** via the first through holes **GO1** formed in the gate insulating film **GI**.

## STEP 2

The gate insulating film (400 nm) **GI**, an a-Si film (150 nm) and an n<sup>+</sup>-Si film (40 nm) are deposited successively using a CVD apparatus in order to form a TFT semiconductor 10. A photoresist is applied, and the n<sup>+</sup>-Si/a-Si film is etched by using a plasma etching (PE)-mode dry etcher to form semiconductor islands. Then, the island-forming photoresist is stripped away by using a chemical solution such as a resist stripper solution (see FIG. 13).

## STEP 3

A photoresist is applied and patterned so as to form openings therein, corresponding to the gate bus lines **GL**, the gate terminals **GT**, the source terminals **ST** and the first and second protruding portions **CN1** and **CN2**. The exposed portions of the gate insulating film **GI** are etched away by using an RIE-mode dry etcher. Then, the photoresist is stripped away by using a chemical solution such as a resist stripper solution (see FIG. 14). By forming the first and second through holes **GO1** and **GO2** in the gate insulating film **GI**, the gate bus lines **GL** and the gate terminals **GT** can be electrically connected to each other.

As illustrated in FIG. 14, the distance  $\beta 1$  is set to be longer than the distance  $\alpha 1$ , where  $\alpha 1$  is the distance between the first through hole **GO1** in the area where the gate

terminal **GT** is formed and the third through hole **GO3** in the area where the first protruding portion **CN1** is formed, and  $\beta 1$  is the distance between the first through hole **GO1** and the storage capacitor stem **CsT**. In other words, the distance ratio  $\beta 1/\alpha 1$  is set to be greater than 1. In this example, the distance ratio  $\beta 1/\alpha 1$  is set to be about 5, for example.

Similarly, the distance  $\beta 2$  is set to be longer than the distance  $\alpha 2$ , where  $\alpha 2$  is the distance between the first through hole **GO1** in the area where the source terminal **ST** is formed and the third through hole **GO3** in the area where the second protruding portion **CN2** is formed, and  $\beta 2$  is the distance between the first through hole **GO1** and the storage capacitor line **Cs**.

Then, the source metal film **SF** is deposited. Glass substrates are carried in a carrier cassette into a deposition apparatus. The substrates are taken out of the cassette one by one with a fork- or plate-shaped arm, and placed on the chuck stage of the pre-deposition web cleaner (e.g., a dry cleaner or a vacuum cleaner) for pre-deposition cleaning. Then, the cleaned substrate is picked up by the robot arm and lifted up off the chuck stage. As the glass substrate is lifted up, it is triboelectrically charged. Different portions of the substrate are separated from the stage at various times due to factors such as bending or warping of the glass being lifted, the shape of the stage, and the position of the lift pins used for lifting up the substrate off the stage.

The triboelectric charging occurs upon lifting the glass substrate off the stage, and the amount of charge to be created depends on the contact area. The substrate being separated from the stage at various times means that the contact area between the substrate and the stage is changing after the start of the separation of the substrate off the stage until the substrate is completely separated from the stage. Therefore, the amount of charge created is also changing during this period while the substrate is being separated from the stage. Thus, the glass substrate is charged unevenly across the surface thereof.

The charge on portions that are connected to SR is made uniform across the glass surface. However, the charge on the gate terminals **GT** and the source terminals **ST**, which are islands, cannot move, thereby creating a potential difference (charge) between SR and the gate terminals **GT** and between SR and the source terminals **ST**.

5           Conductive films are deposited on the glass substrate in such a state by using a reactive sputtering apparatus, or the like. For example, two source metal (Al/Ti) layers are formed (100/50 nm). In the deposition step, on the instant the first layer, the Ti layer, is deposited, the gate bus lines **GL**, the gate terminals **GT**, the source terminals **ST** and the storage capacitor stem **CsT** are electrically connected together via the through holes **GO1**  
10 to **GO3**, thereby bringing the entire substrate to an equipotential state.

Consider a case where the distance  $\alpha$  between the through hole **GO1** in the island formation area and the through hole **GO3** in the area where a line connected to SR is formed is longer than the distance  $\beta$  between the through hole **GO1** to the edge of a line. Specifically, the distance  $\alpha$  is the distance between the first through hole **GO1** in the area  
15 where the gate terminal **GT** is formed and the third through hole **GO3** in the area where the first protruding portion **CN1** is formed, or the distance between the first through hole **GO1** in the area where the source terminal **ST** is formed and the third through hole **GO3** in the area where the second protruding portion **CN2** is formed. The distance  $\beta$  is the distance between the first through hole **GO1** in the area where the gate terminal **GT** is  
20 formed and the edge of the storage capacitor stem **CsT**, or the distance between the first through hole **GO1** in the area where the source terminal **ST** is formed and the edge of the storage capacitor line **Cs**. If the distance  $\alpha$  is longer than the distance  $\beta$ , and if there is no through hole in the area where the storage capacitor stem **CsT** or the storage capacitor line **Cs** is formed, or the through hole is distant from the edge of the storage capacitor stem  
25 **CsT** or the storage capacitor line **Cs**, the charge accumulated on the gate terminal **GT** (island portion) is discharged to the edge of a line covered with an insulating film (the

storage capacitor stem **CsT** or the storage capacitor line **Cs**) while breaking through the gate insulating film **GI**, on the instant a conductive film is deposited.

In this example, the charge accumulated on the gate terminal **GT** flows to the storage capacitor stem **CsT** and then to **SR** via the third through hole **GO3** of the closest first protruding portion **CN1**. Similarly, the charge accumulated on the source terminal **ST** flows to the storage capacitor line **Cs** and then to **SR** via the third through hole **GO3** of the closest second protruding portion **CN2**. Therefore, the entire surface is brought to an equipotential state on the instant a conductive film is deposited, whereby an ESD damage does not occur.

#### STEP 4

A source **Ti** film and a source **Al** film are deposited successively, thereby forming the source film **SF**. Then, a photoresist is applied thereon. The source/drain **Al** film etched by using an etchant such as an  $\text{H}_3\text{PO}_4\text{-HNO}_3\text{-CH}_3\text{COOH}$  etchant. Note that the source **Al** film and the source **Ti** film may be dry-etched successively.

The TFT portions formed in an island structure are etched by using a PE-mode dry etcher so as to form the channels. Note that the channels may be formed by etching successively after the successive dry etching of the **Al** and **Ti** films.

When the channels are formed, the connection patterns **CP** connecting the gate bus lines **GL** with the gate terminals **GT** are also formed. Moreover, the source bus lines **SL** connected to the source terminals **ST** via the first through holes **GO1** formed in the gate insulating film are formed. The source/drain-forming photoresist is stripped away by using a chemical solution such as a resist stripper solution (see FIG. 15).

#### STEP 5

After depositing a TFT protection **SiN** film 20 (200 nm) as a first interlayer

insulating film by using a CVD apparatus, an organic resin film **30** is applied thereon as a second interlayer insulating film. The material of the organic resin film **30** may be, for example, an acrylic resin, a polyimide resin, or the like, to which a photosensitizer is added, that can be exposed and developed, as a photoresist such as a phenol novolac resin. Since  
5 the organic resin film **30** is used as an interlayer insulating film, the organic resin film **30** is such that it is not stripped away in a resist stripping process in a subsequent pixel electrode formation step. This property of the organic resin film **30** makes it different from a photoresist.

A portion of the TFT protection SiN film in the contact hole **CH** connecting  
10 the drain electrode to the pixel electrode is processed with a PE-mode dry etcher while using the organic resin film **30** as a mask. Thus, the drain electrode and the pixel electrode are connected to each other via the contact hole **CH** (see FIG. 16). Note however that since the ohmic resistance between the exposed drain Al film and the pixel electrode metal (ITO) is high, the drain electrode Al film is etched with an  
15  $\text{H}_3\text{PO}_4\text{-HNO}_3\text{-CH}_3\text{COOH}$  etchant, or the like, so as to expose the Ti layer of the source film **SF** (see FIG. 11C).

#### STEP 6

By using a reactive sputtering apparatus, a pixel electrode ITO film having a  
20 thickness of 100 nm is deposited, and a photoresist is formed. The ITO film is etched by using a ferric chloride ( $\text{FeCl}_3$ ) etchant, or the like, to form the pixel electrodes **PE**. Finally, the pixel electrode photoresist is stripped away by using a chemical solution such as a resist stripper solution (see FIG. 10).

An active matrix substrate is manufactured through these steps. The active  
25 matrix substrate can be used in a liquid crystal display device, an organic or inorganic EL (electroluminescent) display device, a plasma display device, an electrochromic display

device, or the like. For example, the manufacture of a liquid crystal display device using the active matrix substrate will now be described briefly. An alignment film is formed on the active matrix substrate and on a counter substrate opposing the active matrix substrate, and the alignment films are subjected to a rubbing treatment. The active matrix substrate and the counter substrate are attached together via a sealant, and a liquid crystal material is filled into the gap therebetween, thus obtaining a liquid crystal panel. Thereafter, SR is removed in the scribing step or the beveling step. COG gate and source drivers are attached to the IC chip attachment area of the liquid crystal panel.

In this example, where portions of a TFT (e.g., the gate terminal **GT** and the source terminal **ST**) are in an island structure, the protruding portions **CN1** and **CN2**, which are continuous with the short ring are placed near the islands, and the third through holes **GO3** are provided in the gate insulating film **GI** above the protruding portions **CN1** and **CN2**. Then, the charge (potential difference) created in the islands can be passed to the protruding portions **CN1** and **CN2** via the source metal film **SF** to be deposited later. Thus, it is possible to prevent an ESD damage.

According to the present invention, it is possible to reduce the possibility of a product to become defective due to ESD. Thus, it is possible to improve the production yield, to reduce the manufacturing cost, and to improve the throughput.

While the present invention has been described in preferred embodiments, it will be apparent to those skilled in the art that the disclosed invention may be modified in numerous ways and may assume many embodiments other than those specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention that fall within the true spirit and scope of the invention.